Processing Strategies and Performances Analysis for Beidou Precise Orbit Determination based on GAMIT

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Outlines

- Research Background
- GAMIT BDS POD Platform
- Processing Strategies and Experimental Setup
- Preliminary BDS POD Solutions
- Future Works

Research Background

This project is to develop an indigenous capability for computing and delivering real-time, regionally enhanced orbit and clock products to support multi-GNSS real-time positioning in Australia and New Zealand.

Output 1: A regional GPS/GLONASS orbit enhancement system that can process data streams from global and national CORS networks to provide high-rate GPS/GLONASS clock and orbital corrections in real-time

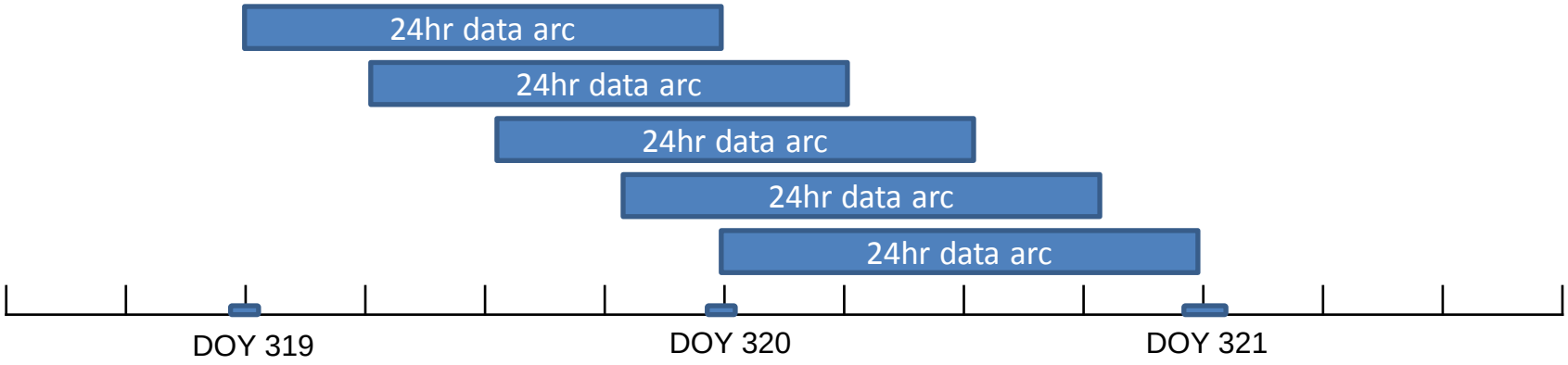
Output 2: A regional COMPASS/QZSS orbit analysis platform that can process QZSS and COMPASS data streams from ground tracking stations in the Asia-Oceania region and provide orbit and clock solutions in near real-time at an accuracy better than their broadcast ephemerides

Research Background

- Develop the Precise Orbit Determination (POD) processing capabilities based on GAMIT-GLOBK.
- Evaluated the impact of the regionally enhanced orbit solution for supporting real-time positioning.
  - The accuracy improvements depends on how well the regional stations can better fill in the gaps of the global networks, rather than the number of additional stations.
  - Regional orbit solution provide decimetre level of accuracy within network converge, however significantly degraded for the rest of region and the orbit prediction.
  - Recommended to use an evenly distributed global network of ~100 stations with ~20 stations within.

GAMIT BDS POD Platform

- Modifications are made to utilize the current GAMIT structure/source code as much as possible.
  - BDS data processing support
  - BeiDou satellite tables
  - BeiDou modelling (attitude/yaw, SRP)
- Sliding Window (SWIN) routine processing



GAMIT BDS POD Platform

INPUTS

Station Coord.
Station Info.
Session Info.
Analysis control files

Raw/RINEX
Sat. orbit IC
Sat. & station clock
Others:
- Luni-solar ephemerides
- nutation
- EOP (UT1, wob)
- Satellite characteristics
- Receiver/Ant. characteristics
- Ocean tide grid
- Atmospheric loading grid
- Tropo. mapping function/grid
- DCB
- Leap seconds
- PCV, PCO

NET_1

Makexp and makex – data preparation

Arc – orbit al ephemeris with partials

Yawtab – satellite attitude values

Grdtab – atmospheric and loading

Model – residuals and partials

Autcln – automatic edit of residuals

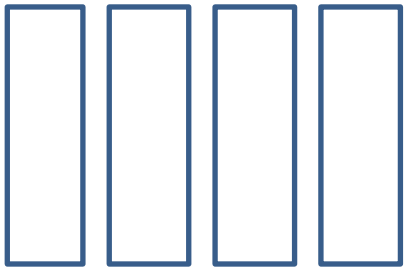
Solve – lease squares analysis solution

Model – updated residuals and partials

Autcln – automatic edit of residuals

Solve – final LS analysis solution

NET_2..... NET_N



Final station coordinates
H-file (covariance matrix)
ZTD estimate

GAMIT Process

Combine quasi-observations “H-files” (loosely constrained solutions & covariance) from multiple networks and/or epochs:

- Time series of station coordinates
- Station velocity
- Orbit and EOP

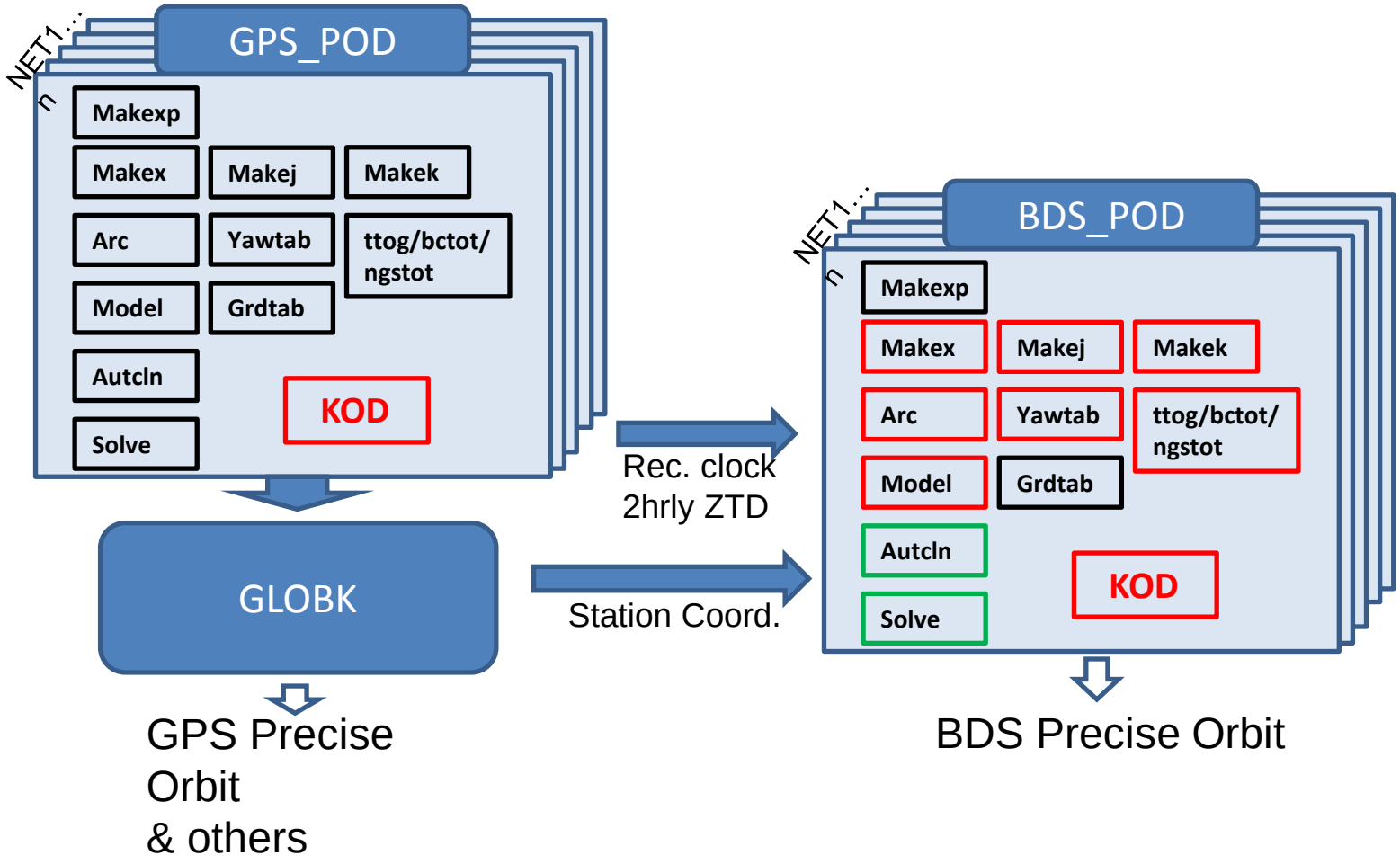
GLOBK Combination

GAMIT BDS POD Platform

- GAMIT modifications:
  - BDS data processing support
    - Conversion of Rinex3 to Rinex2 format
    - Satellite system processing selection (makex)
    - Read, write RINEX and SP3, i.e.
    - Definition for BDS frequencies (B1, B2, B3) and gm &erate constant
    - Broadcast navigation message BDST time adjustment
    - BDS GEO position calculation from broadcast navigation message
  - BDS modelling (attitude/yaw, SRP)
    - Beidou GEO yaw-fixed control
    - Beidou IGSO/MEO yaw-fixed to yaw-steering dual control mode
  - Beidou satellite tables (yaw rate, mass, antenna offset, pcv)
  - Refine data processing control settings

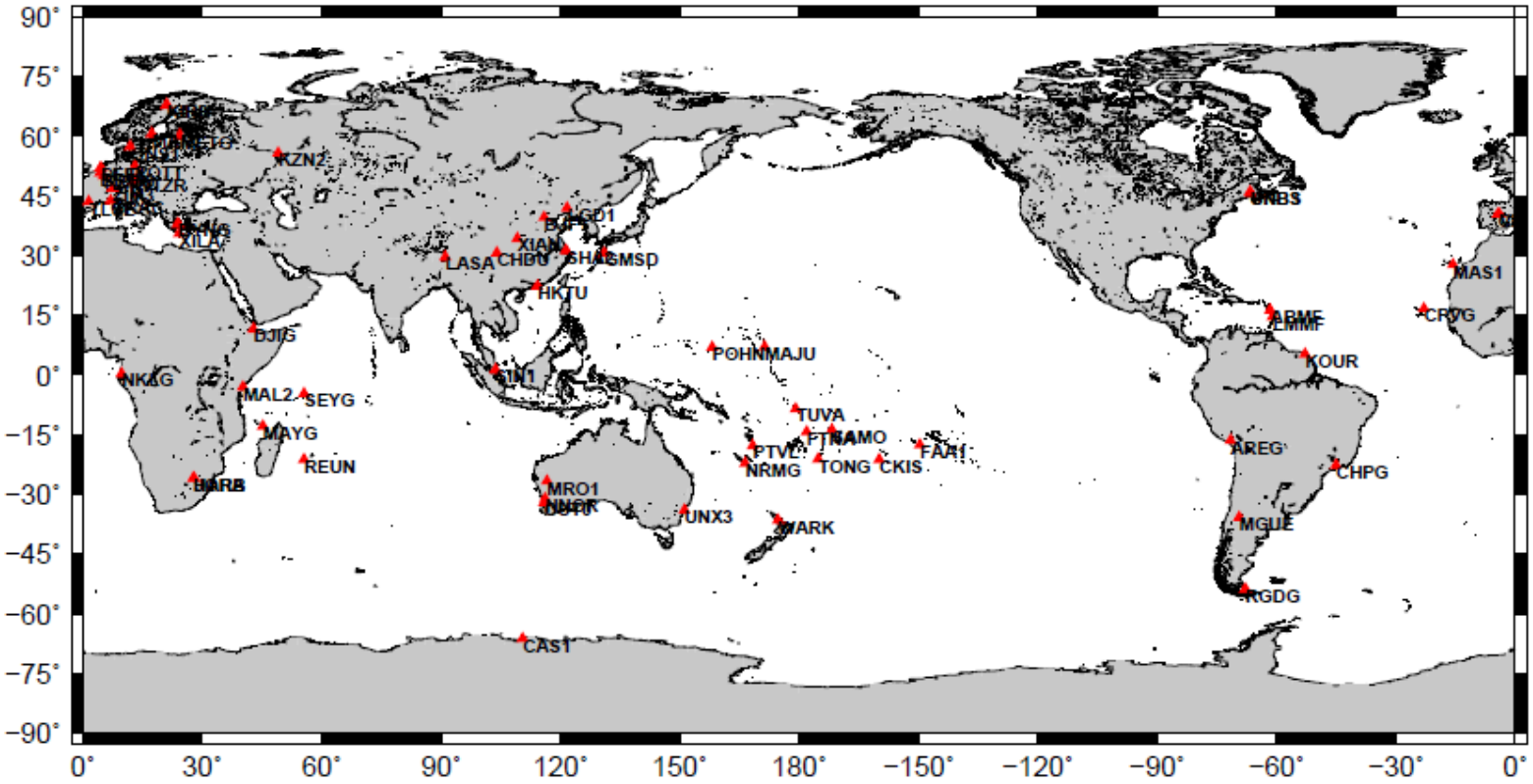
GAMIT BDS POD Platform

Two step BDS processing strategies



Processing Strategies and Experimental Setup

- Campaign duration: 7 days, DOY 180-186, 2014
- Data from MGEX and BETS network
  - Total of 63 stations



Processing Strategies and Experimental Setup

GAMIT-GLOBK Version	10.50
Observation	Compress daily rinex
Sampling interval	30sec
Observation period	24 hours
Cut-off elevation angle	7/10 degrees
Elevation-dependent weighting	Yes
Navigation	BRDC
Precise orbit	WHU
Ocean-Tidal	Yes
Tropo_MFN	GMFH/GMWH
Zenith delay estimation	Yes / 2hr
Zenith Constraints	0.5m
Atomspheric gradients	Yes
Number gradients	2
Met obs source	GPT 50
Radiation Model for ARC	BERNE / BERN2
Reference System for ARC	EGM08
Antenna Model	AZEL
SV antenna model	ELEV

Processing Strategies and Experimental Setup

- BDS satellite PCO setting
  - MGEX convention:

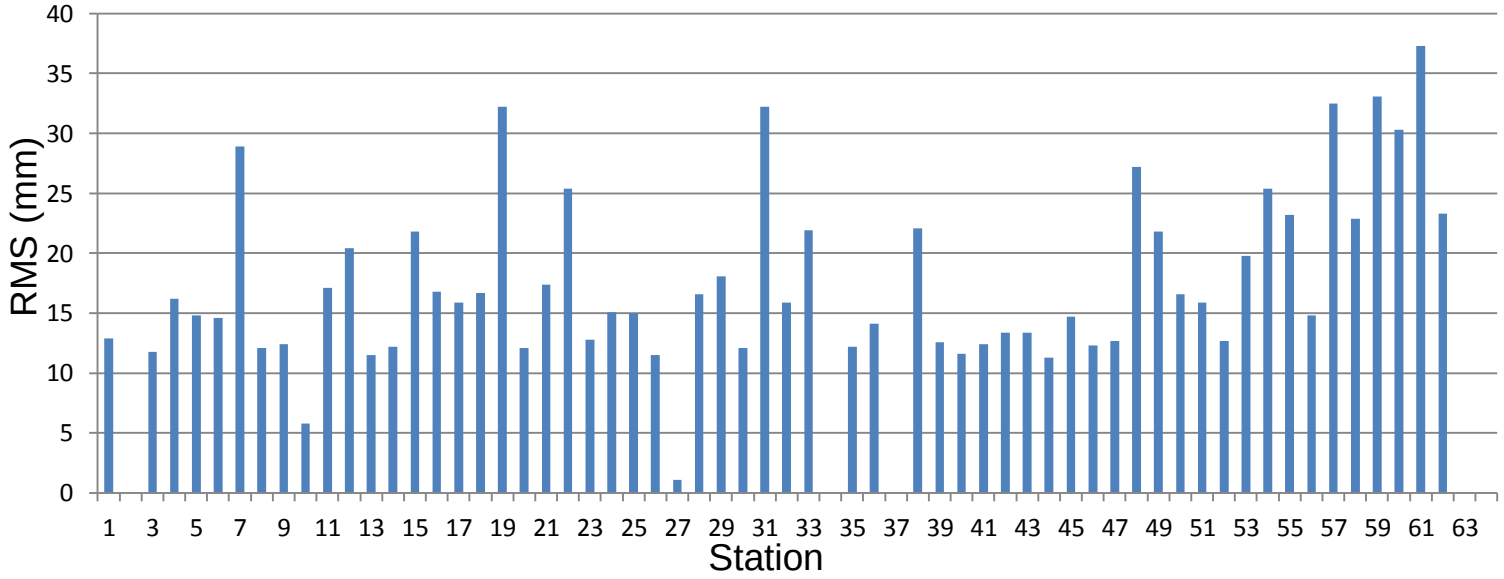
    X-PCO [600mm], Y-PCO [0.0mm], Z-PCO [1100mm]
  - WHU/ESA recent results:
    - Improvements in the MEO satellites is significant in the cross-track direction.
    - No obvious improvement for IGSO satellites

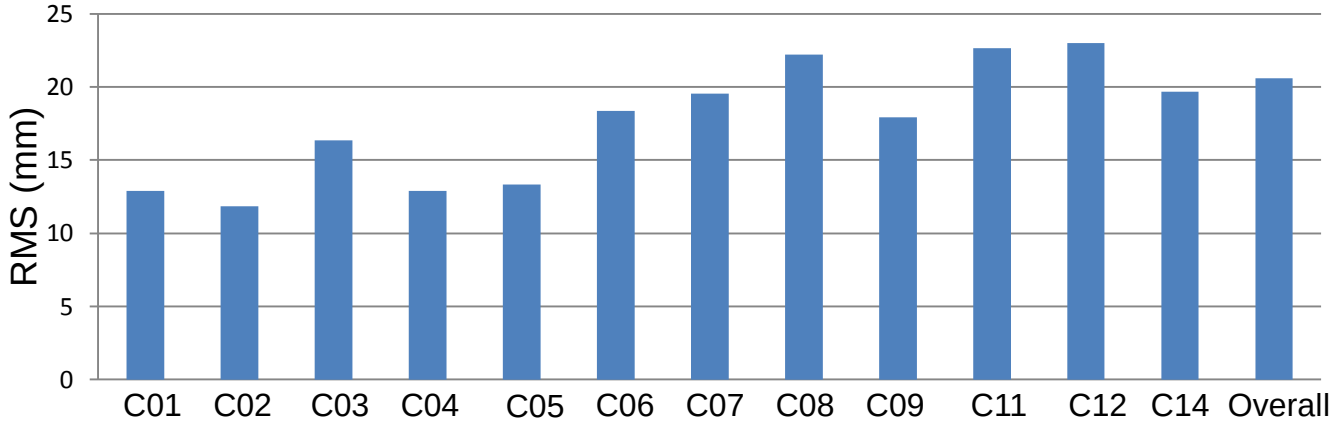
	X-PCO	Y-PCO	Z-PCO				
	[mm]	[mm]	C06	C07	C08	C09	C10
WHU	586.4	0.0	2513.7	2721.9	3440.0	3551.9	4087.0
ESA	549.0	0.0	3049.0	3236.7	3842.6	3973.6	3882.1
	X-PCO	Y-PCO	Z-PCO				
	[mm]	[mm]	C11	C12	C13	C14	Galileo-IOV
WHU	575.0	0.0	1990.7	2249.1	2025.9	2144.3	
	0.0	0.0					1125.0
ESA	549.0	0.0	2069.5	2313.5	2201.8	2311.7	

(Dilssner, 2014, Guo, 2015)

Processing Strategies and Experimental Setup

– Station phase residual: ~20mm





Processing Strategies and Experimental Setup

- Receiver clock jumps:
  - Frequent receiver jump doesn't appear to have much effect on the POD. However, data from BETS network and CUT0 seems to be unreliable and unstable from past experience.

DOY 180, 2014

BJF1	67	CHDU	69	CUT0	26
HKTU	78	JOHA	60	LASA	41
LEID	57	LGD1	12	POTT	13
UNBS	1	UNX3	150	XIAN	78
XILA 45					

- Cut-off angles:

  Elevation cut-off angles setting of 7 or 10 degrees have no obvious impacts on BDS POD

Processing Strategies and Experimental Setup

- Orbit fitting with BERNE (9 parameters) / BERN2 (5 parameters + 1 periodic once per rev sine part in Z-axis direction)

```
Reference T-file: t14180.tmp
External T-files: twhr17990.sp3
Reference T-file span:   28.5 hrs

PRN   Total     delta-X   delta-Y   delta-Z   d-Radial  d-Along   d-Cross
=============================================================================
  1   0.00928   0.01179   0.00827   0.00714   0.01111   0.00914   0.00716
  2   0.00604   0.00494   0.00725   0.00572   0.00693   0.00535   0.00573
  3   0.01100   0.01126   0.00972   0.01189   0.01069   0.01020   0.01201
  4   0.00736   0.00878   0.00666   0.00642   0.00884   0.00660   0.00640
  5   0.00844   0.00931   0.00523   0.00999   0.00728   0.00778   0.01001
  6   0.00496   0.00448   0.00689   0.00252   0.00354   0.00462   0.00633
  7   0.00386   0.00440   0.00434   0.00256   0.00384   0.00454   0.00307
  8   0.00737   0.00655   0.00650   0.00881   0.00792   0.00954   0.00300
  9   0.00418   0.00462   0.00513   0.00221   0.00304   0.00415   0.00510
 11   0.00370   0.00404   0.00312   0.00389   0.00327   0.00322   0.00449
 12   0.00457   0.00347   0.00552   0.00449   0.00538   0.00475   0.00333
 14   0.00223   0.00194   0.00289   0.00167   0.00200   0.00125   0.00305
=============================================================================
MEAN  0.00658   0.00701   0.00626   0.00645   0.00683   0.00649   0.00642
```

BDS orbfit with BERNE SRP model

```
PRN   Total     delta-X   delta-Y   delta-Z   d-Radial  d-Along   d-Cross
=============================================================================
  1   0.03948   0.04180   0.03259   0.04321   0.04432   0.02897   0.04328
  2   0.09007   0.07522   0.07279   0.11568   0.09071   0.05212   0.11573
  3   0.08379   0.08114   0.05192   0.10855   0.08097   0.05019   0.10948
  4   0.03763   0.05382   0.02524   0.02672   0.04480   0.03880   0.02710
  5   0.05119   0.04280   0.03623   0.06867   0.04791   0.02864   0.06888
  6   0.03744   0.03977   0.03520   0.03722   0.04581   0.02888   0.03570
  7   0.04551   0.05421   0.04787   0.03136   0.03385   0.02913   0.06495
  8   0.12827   0.14644   0.11861   0.11767   0.11794   0.11811   0.14659
  9   0.03492   0.03879   0.02588   0.03852   0.03900   0.03583   0.02921
 11   0.02871   0.03951   0.01316   0.02717   0.02343   0.01542   0.04105
 12   0.02418   0.03550   0.01231   0.01848   0.01426   0.00575   0.03895
 14   0.02122   0.02327   0.02027   0.01997   0.02256   0.00829   0.02782
=============================================================================
MEAN  0.06037   0.06426   0.05001   0.06560   0.05844   0.04624   0.07334
```

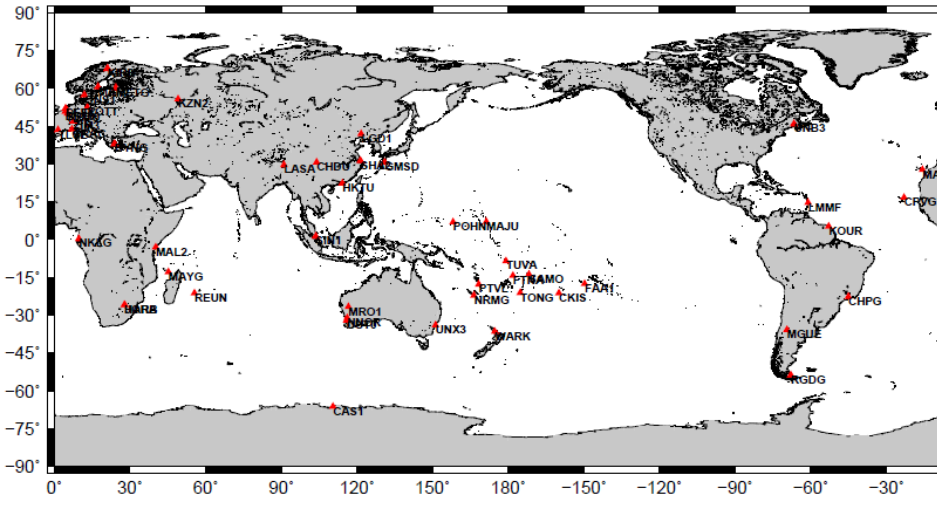
BDS orbfit with BERN2 SRP model

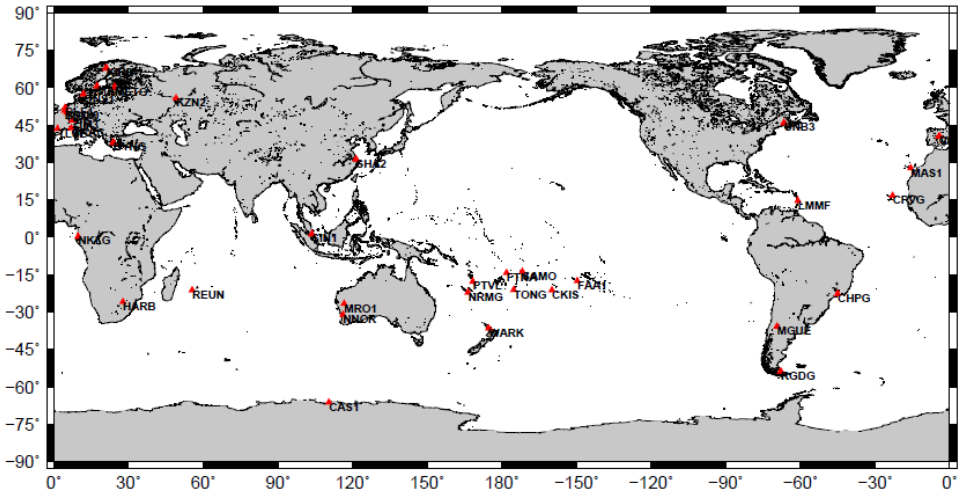
GPS orbfit with igs17990.sp3; BDS orbfit with whr17990.sp3

	BERNE				BERN2			
	Total	Radial	Along	Cross	Total	Radial	Along	Cross
GPS	0.0043	0.0040	0.0042	0.0040	0.0198	0.0187	0.0184	0.0093
BDS	0.0066	0.0068	0.0065	0.0064	0.0604	0.0584	0.0462	0.0733

Processing Strategies and Experimental Setup

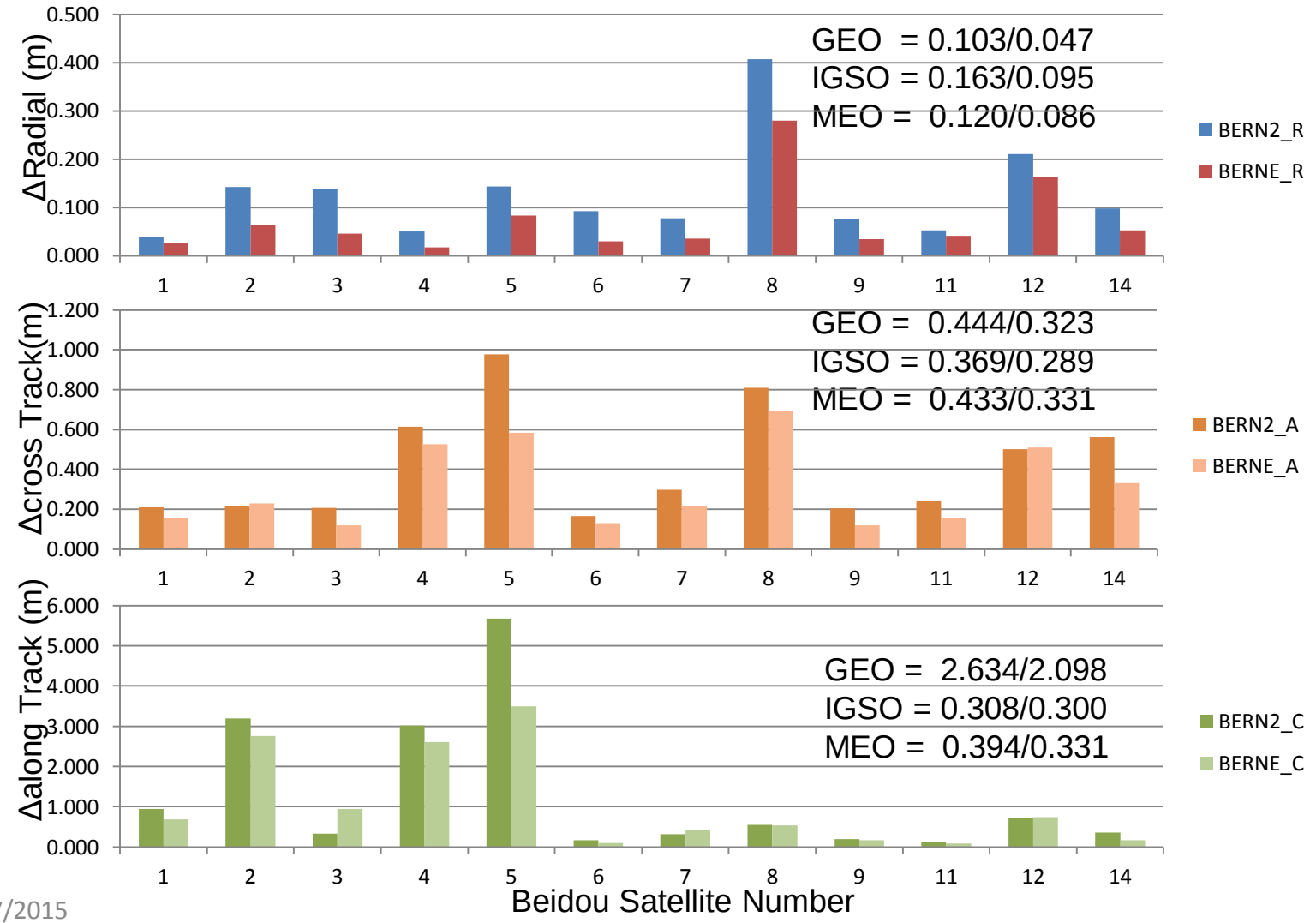
- Three network configurations:
  1. All of the available MGEX and BETS stations (63)
  2. Evenly distributed MGEX and BETS stations, some of European and South Pacific stations are removed (54)
  3. Compacted MGEX and BETS stations from configuration 2, removing stations with frequent receiver clock jump and high phase residuals (34)





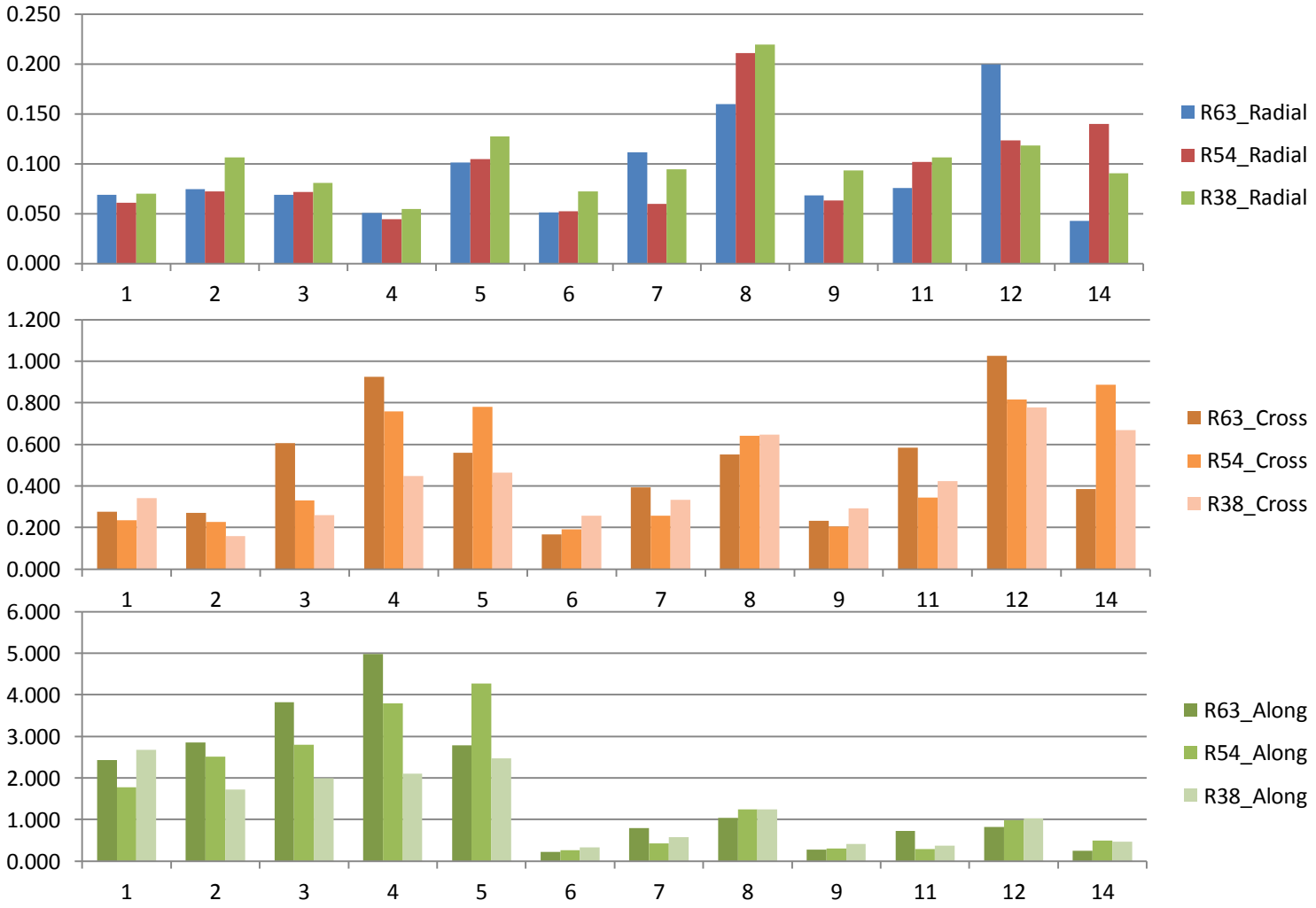
Preliminary BDS POD Solutions

– BERNE2 vs BERNE SRP model



Preliminary BDS POD Solutions

– Network 63/54/38 station configurations



Conclusion and Future Works

- BDS POD processing is achieved through the modification of GAMIT software platform.
- Processing strategies refinement with different SRP models, BDS satellite PCO, cut-off angles, receiver clock jumps and different network configurations.
- With BDS data from 54 MGEX and BETS stations, the platform can constantly deliver BDS precise orbit solution with decimetre radial orbit accuracy.

Conclusion and Future Works

- Future works
  - Evaluate positioning performance with the derived BDS orbit
  - Further investigate BERN2 in GAMIT and explore the mix use of different SRP models for different BDS satellite type
  - Investigation to refine SRP model/processing strategies during yaw manoeuvres
  - Joint Multi-GNSS POD processing
  - Extend to other GNSS constellations

Questions?